Ethnoarchaeology : a Non Historical Science of Reference Necessary for Interpreting the Past

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Ethnoarchaeology appears nowadays as a poorly formulated field. However, it could become a real science of reference for interpreting the past if it was focused upon well-founded cross-cultural correlates, linking material culture with static and dynamic phenomena. For this purpose, such correlates have to be studied in terms of explanatory mechanisms. Cross-cultural correlates correspond to those regularities where explanatory mechanisms invoke universals. These universals can be studied by reference to the theories found in the different disciplines they relate to and which are situated outside ofthe domain ofarchaeology. In the domain of technology, cross-cultural correlates cover a wide range of static and dynamic phenomena. They allow the archaeologist to interpret archaeological facts—for which there is not necessarily analogue—in terms of local historical scenario as well as cultural evolution. In this respect, it is shown that ethnoarchaeology, when following appropriate methodologies andfocussing on the universals that underlie the diversity of archaeological facts, does provide the reference data needed to climb up in the pyramid of inferences that make up our interpretative constructs.

KEY WORDS: ethnoarchaeology; technology; regularities; universals; dynamic approach.

INTRODUCTION

For more than thirty years now, there has been a sort of general epistemological consensus on the role of analogy in archaeological interpretation and on the necessity to call upon laws (Schiffer, 1978), or regularities (Gallay, 1986), for interpreting archaeological facts (e.g. Arnold, 1985; Binford, 1978; Gould, 1978; Hodder, 1982; Hegmon, 2000; Horne, 1994; Kramer, 1979; Longacre, 1978, 1991a; MacEachern, 1996; Miller, 1985; Trigger, 1989; Watson, 1986;

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Wylie, 1985; Yellen, 1977). Thus, to a certain extent, the role of ethnoarchae-ology is acknowledged to be useful, providing “material for building stronger archaeological inferences than do common sense explanations of material culture patterning” (Stark, 2003: 195). However, there is still very little methodological consensus among ethnoarchaeologists, either on the “laws” or “regularities” that should be the goal of our research, or on the methodology for constructing them (e.g. Arnold, 2000; David, 1992; David and Kramer, 2001; Stark, 2003). Lack of such methodological consensus explains why under the label ‘ethnoarchaeol-ogy’, one finds very different kinds of studies, ranging from those that report mere ethnographic observations, to those aimed at constructing cross-cultural correlates transferable to archaeological facts. One consequence is that ethnoarchaeology appears as a poorly formulated field, often criticized by archaeologists (e.g. Stahl, 1993; Wobst, 1978) who often believe that they could do without it.

But can we interpret archaeological facts without a modern reference database? And can ethnoarchaeological studies provide a solid reference database usable in the course of interpreting archaeological facts? By solid reference database, I mean cross-cultural rules of inference, whose conditions of application are well defined and which can be applied directly to archaeological facts presenting the required conditions of application. For this purpose, they are con-structed through controlled observational and experimental procedures, according to explicit theories, independent of the ‘historical’ theories aimed at explaining the archaeological records. The latter is a major point in claiming objectivity on a case-by-case basis when interpreting archaeological facts by reference to modern data (Tschauner, 1996: 24). In this paper, I intend to show that ethnoar-chaeology can provide such reference data, and that their transfer to archaeolog-ical facts allows us then to produce interpretations that are but one step in the pyramid of inferences underlying our historical constructs. Examples are drawn from the domain of technology. As we shall see, the highlighted reference data cover different aspects of material culture. They consist of cross-cultural corre-lates linking material culture to static (technique, economic, social) as well as dynamic (conditions of change in material culture) phenomena. Their founda-tion lies in explanatory mechanisms that call upon laws constraining the material and anthropological universe at the level of properties and processes. The laws themselves are explainable according to theories found outside the domain of archaeology.

I will present these two orders of correlates and show how they can be used in various archaeological constructs. I will then discuss ethnoarchaeology from a theoretical and methodological point of view, suggesting that ethnoarchaeology can provide a solid reference data base and claim to be a necessary science of reference when it follows certain methodological principles.

Ethnoarchaeological studies whose aim is either to test analytical tools (e.g. D. Arnold, 2000; Stark, 2000), or to assess the different factors that can affect material culture (e.g. Bowser, 2000, 2005; David *et al.*, 1988; Gosselain and

Livingstone Smith, 2005; Kramer, 1997; Lemonnier, 1993; Longacre, 1991b; Pétrequin and Pétrequin, 1993), are not considered here, notwithstanding their great value for understanding the complexity of archaeological facts and for re-newing our questions about the past as well as our methods of investigation. These studies do not offer rules of inference applicable to the archaeological record and therefore they do not give us the opportunity to discuss, on the basis of empirical examples, the role of ethnoarchaeology in reconstructing the past. However, their observations are occasionally discussed in order to highlight regularities (as shown in the discussion section that argues in favour of certain regularities).

Ethnoarchaeological studies using the Direct Historical Approach will not be considered either, since these involve correlates valid only within ancient groups that have historical continuity with the present-day groups. These cases are so rare today that, again, they will not enable us to discuss at a more general level the importance of ethnoarchaeology for archaeological interpretation.

CORRELATES BETWEEN MATERIAL CULTURE AND "STATIC" PHENOMENA: SIMPLE CORRELATES

The first category of correlates ethnoarchaeology can propose are simple correlates. They link material culture with so-called "static phenomena." Static phenomena arise from properties of matter, energy, and brain/body. They are non-historical phenomena, "even though they occur and act in the course of history" (Simpson, 1963: 24–25 quoted in Lyman and O'Brien, 1998: 624). In other words, they are cross-cultural and not context-dependent. In the domain of technology, static phenomena refer to the technical acts responsible for the transformation of raw material and the manufacture of artifacts. These technical acts can be studied at different levels:

- the level of the artifact, that is the technical operations and gestures according to which an artifact has been made and used,
- the level of the subject, that is the motor and cognitive skills involved in the making and use of artifacts,
- the level of the production system, that is the interconnection between technical acts described in terms of inputs and outputs,
- the level of the social group, that is the technical tradition transmitted within the group.

As we shall see, it is possible, at each level, to highlight correlates (regularities) given immanent properties (chemical, mechanical, physical, bio-behavioral, socio-cognitive) that constrain the characteristics of the artifacts independently of any historical context. Study of these regularities draws upon different disciplines, as well as upon different theories of observation and explanation (Roux, 2000).

The Artifact: Identifying the Technical Task

In today's archaeological studies of material culture, identifying the technical task is a classical element of analysis. It calls upon regularities discovered either in the field of experiment or ethnoarchaeology. These regularities correlate macro-and micro-features of the artifact with technical operations, defined in terms of techniques (physical modalities by which raw material is transformed) and manufacturing stage. When the technical operation is proper to one and only one *chaîne opératoire*, the correlate may even permit the analyst to infer the *chaîne opératoire* itself. Constructing these regularities follows a mechanistic approach: procedures are designed in order to control the different parameters implicated in the formation of macro- and micro-features of the artifact. Explanations for their formation are drawn from materials science and engineering. The well-founded principles of such an approach have been particularly well expressed in the domain of experimental archaeology and lithic studies where relevant patterns of manufacture and use could be highlighted (e.g. Crabtree, 1972; Pelegrin, 1991; Inizan *et al.*, 1999; Tixier, 1967, 1980; Semenov, 1964).

I will present very briefly one example drawn from my own fieldwork in Khambhat, India, complemented with data from Yemen. (The materials from Yemen were collected by Marie-Louise Inizan [CNRS] in the course of an investigation of carnelian bezel manufacturing techniques.) These two ethnographic situations present distinct stone finishing techniques (grinding, polishing, and shining) with different tools, energy sources and manufacturing times. In order to analyze correlations between physical characteristics of the stones and finishing techniques—and thus the attributes that inform on different finishing techniques—ethnographic data were processed according to a mechanistic approach (d'Errico *et al.*, 2000). Microscopic and roughness analyses (characterizing microscopic features on the surface of the beads and measuring the roughness of the beads with a diamond that produces a high resolution of the profile) were conducted not only with finished beads, but also with beads taken from different stages of the manufacturing process. Microscopic analysis enabled us to understand the transformations undergone by the beads during each operation. Roughness analysis allowed us to quantify these transformations, rendering more objective qualitative perceptions of the different types of surface features. Diagnostic attributes of the techniques used in finishing these beads were then revealed through a mechanical understanding of the three finishing operations, grinding, polishing and shining, which differentially affect the stone.

Harappan beads of the third millennium BC were then studied according to the same analytical methods. Intrinsic attributes analogous to those occurring in the modern referential model were interpreted in terms of finishing techniques. When they appeared to have no ethnographic analogue, hypotheses were proposed based on the mechanisms causing the formation of the different surface features observed in the reference material.

In summary, because the surface features have been studied in terms of the mechanisms explaining their formation, and because the variability of the latter is constrained by the properties of the material, then it is possible to consider the rule of inference "if surface features *i*, then technique *j*" as cross-cultural, and therefore to transfer *j* to ancient surfaces features analogous to the ones ob-served in the ethnographic context. Ceramic studies aimed at highlighting features diagnostic of use or manufacture process follow the same principles, coupling ethnoarchaeological observations with experimentation in order to control the different parameters under study and propose explanations calling upon materials science (e.g. Huysecom, 1994; Gelbert, 2003; Longacre, 1992; Rice, 1996; Sillar and Tite, 2000; Schiffer and Skibo, 1997; Skibo, 1992).

The Subject: Characterizing the Skills Involved in Technical Tasks

Artifacts are manufactured by subjects who develop, for this purpose, techni-cal skills. Characterizing the skills involved in the making of artifacts is a serious line of evidence that should enable archaeologists thereafter to infer the organisation of craft production (Roux, 1990), to assess technological change in terms of continuity or discontinuity (Roux, 2003a), to distinguish between social entities (e.g. Vitelli, 1993), to infer function of objects (Roux, 2003a), and to reconstruct historical scenarios underlying technological change and/or stability (Gosselain, 2000; Gelbert, 1997, 2003).

From the start, interpreting artifacts in terms of skill raises epistemological questions, such as: How are we to reconstruct the particular skills developed by different cultural groups when there are no modern societies that are analogous to those ancient societies? Is it possible to reveal universals on the basis of modern local observations? These questions draw upon comparative psychology, a field in which human activities are studied in terms of cultural variability, as well as anatomical, physiological, biomechanical and cognitive constraints (Bril and Lehalle, 1988). Studies of universalism *versus* particularism are based on field experimentation. Field experimentation must permit a resolution of the dilemma presented by the combination of laboratory analysis and the natural context. In the former case, the following question is asked: to what degree can we generalize the results obtained from simple tasks that are completely devoid of all cultural meaning to real situations in daily life? In the latter case, situations of daily life are characterized by the great diversity of factors involved. This makes it difficult, if not impossible, to individualize the different underlying mechanisms through observations alone. The goal of field experiment is thus to maximize the advantages of the two types of situations (daily life and the laboratory), while trying to minimize their disadvantages and biases.

The observables to be studied are determined by theories. Studies of technical skills relate to the studies of action, which contrast two main theoretical approaches

(Meijer and Roth, 1988; Roux and Bril, 2005). One approach, referred to as the computational or cognitive approach, postulates that action depends upon an internal representation; action is guided by a pre-existing representation. According to this theoretical position, the agent activity is directly caused by some kind of planning that controls the production of behavioural sequences (e.g. Jeannerod, 1997). The second theoretical approach, referred to as the ecological approach, stresses the reciprocal role of the organism and the environment acting as a set of constraints from which behaviour emerges. This approach considers the agent as participating in the world, not as controlling it, and views the action as being the result of the functional coupling between the organism and the environment. This "action system approach" considers itself as more appropriate to the study of everyday life skills (e.g. Gibson, 1979; Reed, 1988). For this reason, the ecological approach has been here preferred to the cognitive approach. It implies different level of analysis of technical actions, from the elementary movement to the plan of action.

I present below two examples of field experimentation aimed at characterizing the skills involved in the making of artifacts, in terms of duration of apprenticeship. The hypothesis used was that apprenticeship varies in length and difficulty depending on the technical task to be achieved. In the first instance, field experimentation was developed in order to characterize stone bead knapping (Bril *et al.*, 2000; Roux *et al.*, 1995). Ethnographic data (interviews and observations) indicate that the craftsmen start to learn the craft around 10 years old, that they work within workshops all year-round, 8 hours a day and that to become an expert 10 years of apprenticeship are required, while only two to three years are necessary for becoming a less expert bead producer (Roux, 2000). Experts are specialized in the manufacture of beads of all shapes and dimensions, whereas less expert practitioners specialize in the making of small beads. In total, we worked with 12 craftsmen, divided between two groups of experts: group 1 in-cluded craftsmen who produced high quality beads daily, while group 2 included craftsmen who produced low quality beads daily. Each craftsman was asked to knap 80 rough-outs of different shapes, dimensions and materials (chalcedony and glass). The knapping process was recorded so that the course of action as well as the characteristics of the elementary movements used in production, and their sequencing, could be analyzed. Two types of recording devices were em-ployed: a video camera situated in the axis of the movement, which recorded the whole knapping activity and a uniaxial accelerometer attached to the hammer head and connected to a portable computer that measured the acceleration of the hammer.

The analysis could then be based on three types of data: the finished products (the beads), the strategy used by the craftsman, and the structure of the movements. The finished products were analyzed using a pattern recognition program, with automatic analysis of each contour (Roux *et al.*, 1995). The strategies followed by the craftsmen were analyzed using a time-series procedure. The succession of actions (i.e. the plan of action) was noted, as was their duration. The structure of the elementary movements was analyzed in terms of movement duration and variation of the acceleration of the hammer. The results very strongly suggest that expertise rests on control over the elementary actions, rather than on the course of action. More precisely, the level of expertise could be defined, not from the planning abilities involved in production, but rather from the mastering of the dynamics of the interaction between the subjects and their environment in the realization of the action. These results explain the variation in apprenticeship duration depending on the type of bead to be knapped. In effect, the knapping of the different types of beads requires production of different types of flakes, which imply variations in the elementary actions. Consequently, the mastering of knapping of beads of all shapes and dimensions requires long years of practice.

According to the same principles, field experimentation had been conducted to characterize the skills involved in ceramic wheel-throwing technique (Roux and Corbetta, 1989, 1990). Ethnographic data indicate that, among potters working all year-round and starting the craft at the age of 8 years old, it takes 10 years of apprenticeship to master the wheel-throwing technique, and only 2–3 years for mastering the coiling technique. Mastering the wheel-throwing technique means to be able to throw pots of all sizes and shapes. The same is true for the coiling technique. The field experiment consisted of assembling five groups of apprentice potters and non-potters (different age groups). The former were asked to throw the vessels made at each stage of apprenticeship. The throwing process was recorded with a video camera and analyzed in terms of inter-subject and inter-group variability, as well as compared with the coiling process. End-products were kept and analyzed in terms of regularity. Both groups of potters and non-potters were then given tests designed to measure their mastery of the perceptual-motor capacities necessary for throwing vessels of different sizes. Results show that potters progressively construct the capacities involved in the wheel-throwing technique, and explains why the regulation of a large number of variable inter-digital or inter-palm pressures applied on clay with the help of rotative kinetic energy (RKE) is much longer and more difficult to master than the regulation of pressures applied on clay without the help of RKE and which call upon skills that are developed otherwise for domestic activities (e.g. making bread).

In both examples, stone knapping and wheel throwing, expertise consists of mastering a wide array of elementary movements necessary for making ob-jects of all sizes and shapes. Analytical procedures highlight how bio-behavioral constraints ensure that competencies are constructed progressively, whatever the cultural representation of the expected competencies. In this regard, field experiments permit us to distinguish between "universals" (the relative length of apprenticeship given bio-behavioral constraints) and "cultural particulars," deriving from the social and physical environment, cultural representations of competencies, and methods and techniques of education (Roux and Bril, 2002). Psychological studies have shown that ten years is the minimum time required to become an expert in a practice calling upon skills that are not developed by everyday life activities, be it purely cognitive or a motor activity and whatever the cultural context (e.g. chess or sport—Ericson and Lehman, 1996). From this point of view, ten years to become an expert in knapping all types of beads or in throwing all kind of pots may well be considered as a cross-cultural regularity. Hence, the two general reference propositions: "the wheel throwing technique requires a much longer apprenticeship (around 10 years) than the coiling technique (around 2–3 years)" (Roux and Corbetta, 1989, 1990); "the long stone beads require a much longer ap-prenticeship (around 10 years) than the short ones (around 2–3 years)" (Bril *et al.*, 2000; Roux *et al.*, 1995); or else, the two following rules of inference, "if wheel thrown pots, then long apprenticeship," "if long stone beads, then long apprentice-ship." The attribute "duration of apprenticeship" or "high learning cost" can be transferred onto archaeological wheel-thrown pots or long stone beads, given the cross-cultural regularities in these activities, explainable in terms of constraints at the bio-behavioral level. It can also be transferred to other objects (e.g. chipped stones) whose manufacture requires skills necessitating the progressive mastery of a wide array of elementary movements (Bril and Roux, 2002).

Applied to the archaeological record, the attribute "high learning cost" has enabled us to infer subsequently that artisans making wheel-thrown pots or long stone beads were specialized, given the contexts of multiple techno-economic tasks: in such contexts, all the tasks that require a long apprenticeship cannot be practiced by all the members of a community (Roux, 1990). Craft specialization is here defined as the takeover by part of the population of a craft activity, the products of which are consumed by the community. The community is considered in the broadest sense of the word: village or regional community. This definition in no way judges the economic status (full-time, part-time) or social status of the artisans. It only describes the distribution of activities within a community (Roux and Corbetta, 1989). The attribute "high learning cost" has also enabled us to conclude that artisans producing wheel-thrown pots or making short beads were not the same as the ones making only (as shown by a combination of qualitative, quantitative and spatial data) coiled pots or short stone beads since the latter would not have the necessary skills for making wheel-thrown pots or long stone beads. Long learning skills restricted to the manufacture of specific categories of objects, can be significant too for inferring that function (in the broad sense of the word [material, social, symbolic—see Gardin, 1979]) of the new skill objects was different from that of the other objects (Roux, 2003a; Roux and Matarasso, 2000). Finally, the attribute "high learning cost" has enabled us to: a) conclude that there is a rupture at the technique and/or skill level between production of the former and the latter artifact types, which is a first step necessary for understanding the evolutionary trajectories of techniques; b) to wonder if emergence of new “high learning cost” skills imply, depending on the period, particular forms of organizational structure, i.e. for the 5th–3rd millennium BC, chiefdom, palatial or temple societies with artisans attached to the elite (Roux, 2003a). Going one step further, characterizing expertise in stone knapping has even enabled us to consider the necessary bio-behavorial conditions for the emergence of stone knapping skills (Roux and Bril, 2005).

The Production System: Interconnecting Technical Acts

The construction of rules of inference aimed at interpreting past techno-systems can also take place within theoretical frameworks independent of theories specific to archaeology or to history. As for skills, interpreting artifacts in terms of production systems raises epistemological questions: How are we to reconstruct the particular techno-systems developed by different cultural groups when there are no modern societies that are analogous to those ancient societies? Is it possible to reveal universals on the basis of modern local observations? These questions draw here upon economy and the search for quantitative models processing cross-cultural baselines against particular historical data. In the domain of technology, where the scope is to analyze a set of technical chains oriented towards the production of a restricted number of objects, theoretical models for representing complex systems are quite limited in the sense that most of them are, a priori, market economy orientated. But the hypothesis of a market economy for ancient societies can come only after a previous collection of data on the economic life that takes place “under the market” and that Braudel (1980) named “material civilization.” In order to collect these data, and thereafter question the more general functioning of the society, economists have designed different formal methods among which is *activity analysis*. This formal method, based on the works of von Neumann (1945), Dantzig (1963), and Koopmans (1951), is most appropriate since it is aimed at representing technical acts on the basis of local observations (Matarasso and Roux, 2000; Roux and Matarasso, 1999). It has been developed to describe production systems in many field of economic science (from energy and agricultural economics to operational research) and has been applied to a number of case studies. It can enable archaeologists to ascertain, from the number of craft products found on archaeological sites, the annual craft production rate, the number of workers involved, and thereafter, according to the context, the techno-system. The economic estimates are based on cross-cultural rules of inference, enabling us to associate artifacts with quantitative attributes related to consumption and production.

The basic idea of activity analysis is to deconstruct a complex production process into its constitutive elements, called *activities*. An activity is comprised of an elementary technical act described on the basis of its input and output (consumption and production). Activities are connected to each other through their respective inputs and outputs. The rule is that the resources consumed in each activity have to be logically produced by other activities. As a result, the general model enables us to infer, from the final products, the primary components of the technical system: raw material, waste, tools, workforce and so on. Complementary factors may exist among the same activities. They structure the alternatives to a productive system. Activity analysis enables us to highlight constraints and alternatives within a formal framework designed in order to provide quantifiable results. In other words, activity analysis has the potential to measure systems of production and to envision alternative forms of organization.

The procedure for interpreting past techno-systems according to activity analysis follows three steps, here illustrated through a case study using stone beads (Roux and Matarasso, 1999). (1) Elementary technical activities are quantified in a group involving both consumption (in terms of raw material, energy, duration of work, etc.) and production (number of objects made per day, etc.). Quantification focuses on determining factors related to the properties of the material resources, environment and subjects. This includes, for example, the possibilities presented by the raw material itself: given stone cores of certain dimensions and utilizing a particular method and manufacturing technique, are there limits on the number of beads one can produce? As a result, the quantitative data related to technical operations have cross-cultural value. For each elementary operation or activity, a conventional unit of measure must be defined. Diverse conventions can be used. The work time consumed by an activity can be measured in hours, days, etc. The activities can be standardized according to the annual activity of an artisan, or according to the conventional number of objects produced by the activity (consumption and production per 1000 objects produced). For less homogeneous operations, as in heat/color treatment, which takes place in furnaces unevenly filled with beads of various dimensions, the consumption and production of beads is measurable against a standard of 10,000 beads. As for the goods, most of them are measured by a “natural” unit: raw nodules and fuel are measured by the ton; beads by their different stages of manufacture in units of 1000; and labor in terms of workers per day (in the model, a day comprises 6 working hours).

(2) Networks or technical sequences are defined in the group. They correspond to the articulation of technical operations aimed at the production of a unique type of object. Technical sequences or associated activities may be rel-atively independent of each other, although there may be competition for the consumption of primary resources. In Khambhat, technical sequences (extraction, knapping, abrading, drilling, polishing) are specific for each bead type which com-pete for the labor of specialists, the use of furnaces, the consumption of energy and/or the use of polishing instruments. These networks or technical sequences are nonetheless autonomous: they can be achieved independently of each other. They are not linked to each other by the circulation of goods, and therefore may be

considered as well defined sub-systems of the global system. Technical sequences act as references for interpreting the past.

(3) The complete techno-system is re-constructed. A techno-system corresponds to a complex combination of technical activities or to an association of networks. It can be described on the basis of the technical sequences and contextual data, which give structure to the production system. Extant techno-systems cannot act as a referential model for interpreting the past because techno-systems, by definition, correspond to particular cases. Only elementary activities can act as such referential models. Only in this manner can we assess the technical ele-ments, which do not vary between the past and the present. Past techno-systems are reconstructed by reference to quantified, extant elementary operations. Ar-chaeological variables structure the possible alternatives for the organization of the techno-system.

In the case of the Harappan stone bead techno-system, the model has been modified according to the specificity of the archaeological data. In particular, the ancient drilling and polishing procedures were different from the present-day ones. Quantitative data have thus been adjusted for each procedure. Then the initial population of Harappan stone beads was assessed; it was hypothesized that the number recovered represented 1/100th of the initial population (our first estimate, 1/1000th, appeared to be too high after taking into account the surface areas and the number of sites excavated), and that these beads were produced over 500 years. After processing a number of Harappan stone beads according to activity analysis, the following interpretative propositions were made (Roux and Matarasso, 2000):

- The number of specialists involved in the production of stone beads was limited. When converting the annual production of beads into number of craftsmen (i.e. number of working days to make *n* beads), we reached very low figures (based on polishing techniques: 16, 8 or 2).
- Specialists worked in an integrated manner, executing all the tasks of the technical sequence. The hypothesis of a non-integrated production process, where specialists concentrated on particular elements in the process (as in Khambhat), resulted in estimations of specialist involvement that are low to the point of absurdity (less than 1 individual, less than 1 driller, etc.)
- Given the limited annual production of beads, specialists were apparently involved in other work as well, not only in bead manufacture. These other tasks would have been, in part, craft specialties. Often other categories of objects are associated with stone bead workshops (steatite beads and seals, shell artifacts, weights, etc.). The common denominator is the skills necessary for their manufacture (i.e., skills in knapping, drilling, and polishing, [Pelegrin, 1994]), and so it is likely that these specialists were involved in manufacture of these other artifact categories as well.

- Harappan carnelian long stone bead production rates appear to be so low that one cannot hypothesize a commercial enterprise, in the usual sense of the term. One must therefore envision some kind of *ad hoc* productive system responding to a limited demand (involving religious and/or elite activities, for example). Production for elites allows us to suppose that the artisans specialized in the manufacture of carnelian long beads were "attached" to such elites, *sensu* Brumfiel and Earle (1987).

These interpretations contribute to the more general debate concerning the role of craftsmanship in the formation of the state. Contrary to what was intuitively supposed, the evidence here suggests that craftspeople involved in lapidary work were too few to represent a real 'class of craftsmen.' As far as the development of carnelian long stone bead production is concerned, it appears to have been a response to the demand of an elite. It cannot be taken as an argument in favor of theories according to which the origin of the state is to be found in a problem of the redistribution of goods.

The example given here bears on Harappan stone bead production. However, because the model used is quantitative and cross-cultural, it can be applied to any site containing stone beads. The specificities of each archaeological site will structure the reconstruction of the techno-system. Similar models can be elaborated with other materials like ceramics, with the extant context of observations allowing the quantification of elementary technical acts and the characterization of technical sequences.

The Social Group: Characterizing Techno-Stylistic Traditions

Technical acts can also be studied at the social level. The ensemble of technical acts involved in the manufacture of end products may be considered as the expression of a way of doing things, a so-called "technical tradition." The different factors (technical and cultural) that generate variable technical traditions are the object of numerous studies belonging to different theoretical approaches (e.g. Dobres, 2000; Lemonnier, 1993; Pfaffenberg, 1992; Schiffer and Skibo, 1987, 1997; Shennan, 2002; Skibo and Schiffer, 2001). The question raised here is not about the factors at the origin of various technical traditions, but about the possible cross-cultural correlates between technical traditions, identifiable in the archaeological material, and social groups.

The first correlate links technical traditions, characterized at the level of either the *chaîne opératoire* or technical operations, with social boundaries. This correlation has been observed in multiple instances (e.g. Degoy, 2005; Dietler and Herbich, 1998; Gallay, 2007; Gosselain, 1992, 2000; Livingstone-Smith, 2000; Stark, 1998; Stark *et al.*, 2000), although these social boundaries refer to differ-ent socio-cultural realities (linguistic group, ethnic group, caste, class, faction, gender and so on). Mechanisms explaining such correlations may be sought in the apprenticeship process at the individual and collective level, given what could be socio-cognitive laws. At the individual level, any cognitive and motor skill is learned through apprenticeship according to a model. In other words, apprentices learn according to what the master shows or teaches. They never learn by inventing, whatever the context of apprenticeship (Bril, 2002). When there is "invention" in the process of learning, it does not bear on the technique, the method or the related skills, but on the different values a technical operation can take and which do not imply new specific skills (e.g. invention in painting design, Dietler and Herbich, 1998). Now, learning skills do not correspond to a simple imitation process, but to a process of discovery by the learner of the way in which properties of the body can be used in a task achievement (Bril, 2002, 1995; Reed and Bril, 1996; Newell, 1996) whose cultural component is defined in terms of manufacturing techniques, methods and gestures. At the end of the apprenticeship process, the skills necessary for reproducing the tradition, and only these skills, are literally "embodied."

These skills then participate directly in the maintenance of the tradition, in the sense that it becomes difficult for the subject to conceive of making things in other ways, given the cognitive and motor skills they have developed which act as "fixers" of world views. In other words, a technical tradition gets reproduced through the apprenticeship process, which fixes the tradition at the individual level. Individuals are part of social groups (of whatever size or socio-cultural nature). At the collective level, these groups ensure the reproduction of the tradition through transmission networks, here to be understood as networks favouring vertical and/or horizontal transmission. These transmission networks develop *habitus* (Bourdieu, 1977) proper to each social unit, the boundaries between *habitus* (here the technological traditions) then are expressed as social boundaries. The fact that there exist different technical traditions side-by-side indicates thus that the apprenticeship process took place within different groups who have developed different *habitus* or practices. For example, in North India, the wheel-throwing technique is transmitted vertically from father to son only, and the non-wheel fashioning techniques from mother to daughter only. It follows that wheel fashioning and non-wheel fashioning techniques distinguish between two groups of potters whose learning networks do not interfere, and indicate a social boundary to be interpreted here in terms of sexual division of labor.

In Mali ceramic fashioning techniques are practiced within endogamous castes belonging to different ethnic groups (Gallay, 2007). Each ethnic group has its own technical tradition for making earthenwares. It follows that the different technical traditions, present side-by-side in the Inland Niger Delta, indicate social boundaries interpreted here as ethnic groups. At the same time, a single technical tradition can also be practiced by different socio-cultural groups whose transmission networks have merged generally through horizontal transmission (e.g. Degoy, 2005). But, this widespread technical tradition will still differ from another tradition, thus express social boundaries. It follows that, at this stage, one general proposition can be retained as cross-cultural: "a technical tradition, defined at the chaîne opératoire or the technical operation level, corresponds to a social group." This proposition can be expressed under the form of the following rule of inference "***if*** distinct technical traditions, ***then*** distinct social groups." Its foundation rests on universals pertaining to mechanisms of learning and the transmission of technical tasks, and whose explanation is found in psychological and sociological theories (in ecological theory and theory of practice respectively).

If the cross-cultural nature of the correlation between technical traditions and social boundaries can be considered as well-founded given socio-cognitive laws, it may also be true that the interpretation of social boundaries in terms of social groups may be context dependent (Hegmon, 1998). Highlighting correlations that links the specific spatial patterning of technical traditions with social groups is in fact one challenge tackled by few ethnoarchaeological studies (Arnold, 2005; Dietler and Herbich, 1998; Gallay, 2007; Kramer, 1997; Stark, 1994). These studies examine how to associate particular quantitative pattern of techno-stylistic features in space with social groups. The hypothesis is that different social groups will create different quantitative patterns in space. One of the most elaborate studies on this topic is that of Gallay (2007). He proposes a spatio-quantitative model taking into account bio-behavioral constraints (the distance one man can walk within a day), modalities of objects distribution (market *versus* non market), and modal-ities of women circulation (endogamous *versus* non endogamous). The model distinguishes two concentric zones: one central zone with a strong concentration of pottery from the same technical tradition corresponding to the ethnic group, and one peripheral zone with mixed traditions corresponding to the circulation of pottery beyond the ethnic territory. The model is considered valid for comparable contexts: contexts where part of the pottery is not distributed through markets, but through direct exchanges, and the potters are specialized and endogamous. From this model, the following rule of inference may be derived: "***if*** spatio-quantitative model with two marked concentric zones, ***then*** endogamous society with peripheral markets and specialized potters." In order to test and produce more such models, more comparative studies are needed. If these follow similar methodologies, they should permit us to highlight how quantitative models of spatial patterning may vary according to different contexts, these contexts determined by bio-behavioral, economic and anthropological constraints.

CORRELATES BETWEEN MATERIAL CULTURE AND DYNAMIC PHENOMENA: COMPLEX CORRELATES

The second category of correlates that can use ethnoarchaeology to link material culture to dynamic phenomena, and are here called "complex correlates."

Dynamic phenomena arise from the processes that result in historical evolution. "Processes" are here understood as diachronic changes in mechanisms (David and Kramer, 2001:50) responsible for actualizing historical change. Like static phenomena, they are supposed to be cross-cultural, non-historical phenomena, "even though they occur and act in the course of history" (Simpson, 1963:24–25 quoted in Lyman and O'Brien, 1998:624). In the domain of technology, the dynamic phenomena here under scrutiny do not thus correspond to the technological changes themselves. The latter are by definition particular historical scenarios, and are not reproducible (Gallay, 1986). In this regard, the study of present-day technological change cannot in itself act as a reference database for interpreting ancient technological change. What corresponds to dynamic phenomena, supposedly responding to general laws, are the actualization conditions of technological change as proposed by the dynamic system approach (Roux, 2003a)), that is the conditions that transform possible, virtual scenarios into actual scenarios.

According this approach, new systems emerge from a complex set of interactions among internal components and self-organize over time (Smith and Thelen, 1993; Thelen and Smith, 1994; see also ecological perception theory, Gibson, 1979). From this perspective, technological change is conceptualised as the result of a dynamic and complex process emerging from interactions among properties of the constituting components—the technical task, the environment and the intention of the subject. Because the patterns of interaction are complex, it is impossible to define a hierarchical order or assign a particular determinant status to any specific component of the system. It follows that it is also impossible to identify regularities at this level. We are facing local scenarios, whose nature is historical and which cannot serve as a reference base for interpreting archaeological data. From this point of view, mere reports on particular historical technological change cannot serve to better understand past technological changes. To the question of why tech-nological change happens at a specific moment, the dynamic systems perspective suggests considering the critical values at which the components of a system are effective in provoking a qualitative change. From a technological perspective, the critical values are represented by the context in which the technological change takes place, i.e. the contexts of craft production and transmission. Contexts of craft production refer to the organization of craft production (e.g. specialized *versus* domestic, attached *versus* independent artisans); contexts of transmission refer to the modes of transmission: vertical, horizontal, direct, indirect. Contexts of craft production and transmission represent the conditions enabling the actualization of technical change and, as such, act as evolutionary forces. They correspond to the regularities that one can expect to identify in the actualistic domain when study-ing technological change. They are then expressed under the following form: in contexts ***Cp*** (context of production) and ***Ct*** (context of transmission), then histor-ical scenario ***i*** (technological change characterized by ***n*** properties). Applied to archaeological data, they can be expressed under the form of a rule of inference:

in context *Cp*, if historical scenario *i* (technological change characterized by *n* properties), then contexts *Ct*, *Ct* being the unknown variable not verifiable empir-ically (unlike *Cp* and scenario *i*). Few ethnoarchaeological studies have studied technological change following the dynamic system approach, even though the relevance of this approach is acknowledged by a few archaeologists (Ingold, 2001; Stout, 2002).

I will give one example in order to show how properties of technological change can be characterized, and how actualization conditions of technological change observed in a particular ethnographic situation (the contexts *Cp* and *Ct*) can be highlighted and validated.

This example is drawn from an ethnoarchaeological study of technical borrowing led by A. Gelbert (2003) in Senegal. Technical borrowings are observed between two distinct ceramic traditions associated historically with two ethno-linguistic entities (Halpulaar'en and Mande) and are studied in terms of cross-community relationships. Among these borrowings (observable for each step of the manufacturing process), Gelbert has observed the borrowing of the moulding technique for making the lower part of the vessels. Borrowing of convex moulding (tradition 2) has been observed among artisans who earlier used the technique of hollowing a lump of clay (tradition 1). A fine technological analysis demonstrates that adopting convex moulding involves no motor or technical constraints but it produces a perceptible decrease in the functional properties of water jars (strength and pots' ability to cool water) and allows a marked decrease in fashioning time (moving from hollowing to moulding reduces the time needed for fashioning by nearly 60%). It does not involve any constraints in raw material acquisition or preparation. Potters clearly perceive the difference between hollowing a lump of clay and convex moulding. The potters who adopted moulding claim that they wanted to increase the speed of their production because they are producing on a large scale. The dynamic of the borrowing process results from interaction between its different components and properties as described above (task, en-vironment, subject). Properties of the borrowing (the moulding technique) have been characterized in terms of a technique that is easily learned and that presents a techno-economic advantage compared to the alternative of hollowing a lump of clay. Its context of actualization implies that potters of tradition 1 produce on a large scale and have at least indirect contact with potters from tradition 2. On the basis of this actualization context, the following rule of inference could be formulated: in a context of specialized and large scale production, if we observe among potters of a particular tradition the borrowing of a foreign fashioning technique that is both fast and easy to learn, we can infer that artisans have experienced at least indirect contact with the foreign tradition.

In Mali, Alain Gallay (pers. comm.) has observed the borrowing of convex moulding by potters who do not produce on a large scale, but on a small scale. This does not mean then that the actualization context of the borrowing process is invalidated, but that its formulation has to be revised. More precisely, the parameter 'production on a large scale' is not valid any more and becomes 'production on a large or small scale.' In the two case studies mentioned, the potters, either from the local tradition or from the foreign tradition, make comparable utilitarian vessels. I propose to enrich the actualization context by adding one condition: the objects made traditionally and the ones made with the borrowed technique had a similar function. It follows a new formulation of the rule of inference: in a context of specialized production, if low learning cost techniques presenting a techno-economic advantage and applied to comparable functional objects present a high rate of diffusion, then we can infer that artisans have experienced at least indirect contact with the foreign tradition. These contacts are the evolutionary forces underlying the borrowing phenomena. But, the regularity here highlighted can again be subject to revision if comparable borrowing is observed under different contexts. Here, more comparative studies, using comparable theoretical frameworks and field methodologies are seriously needed.

DISCUSSION

The various examples given above show that it is possible to construct simple and complex cross-cultural correlates whose validity can be tested against independent empirical data. Static and dynamic correlates may be considered here as middle-range theories, that is theories independently tested (Binford, 1983), although it should be clear that these correlates are theory-laden (Tschauner, 1996) and do not pretend to be 'symptoms' of past systemic contexts (Binford, 1981). They are instead expressions of non-historical phenomena, given uniformitarian laws that constrain properties and processes characterizing material culture and behavior. They are theory-laden in the sense that they are but one step of the interpretative process. Nonetheless, their necessary and efficient nature for interpreting archaeological traces and facts is obvious when examining the pyramid of inferences used in forming historical constructs.

The necessity of highlighting static and dynamic correlates has been underlined by different trends in archaeology such as Processual, Behavioral Archeology or Symbolic Archaeology, even though there has been disagreements on the way "middle-range theory" should be used (e.g. Schiffer, 1988). Such a convergence stems, at least in our case, from epistemological concerns, and in this regard, from principles such as the logicist ones initiated by Gardin (1990). According to Gardin, the structure of our interpretative constructs corresponds to pyramids of inferences, whose validity should be assessed against empirical data (Gardin, 1990). When seeking to construct empirically well founded correlates or rules of inference, there are several possible approaches: the experimental approach, which permits a rigorous control of the parameters at work, the comparative approach which permits the isolation of explanatory parameters, and finally the contextual approach, which permits definition of the context in which the regularity operates (Roux, 2000).

In the domain of technology, simple correlates provide rules of inference with respect to qualitative (chaîne opératoire, function, skills) and quantitative phenomena. These rules of inference have been shown to be cross-cultural, their explanatory mechanisms responding to universal properties and process. They permit an interpretation of material culture in terms that are not context-dependent; for example, interpreting the wheel-throwing technique in terms of a craft that takes a long time to learn is valid for any culture. The resulting interpretations are then applied differently according to the archaeological context. They allow us to make statements touching upon different domains, synchronic (socio-economic statements) as well as diachronic (properties of technological change). Simple correlates are built within different theoretical frameworks and according to different theories of observation, each of them belonging to disciplines which are non-historical, situated outside the domain of archaeology (Gallay, 1986): materials science, psychology, economy, sociology. Their explanatory mechanisms are testable against empirical data whose relevance depends on the principles of observation. These principles of observation imply general field experimentation or comparative studies which permit us to control the parameters underlying the variables being studied. The great strength of actualistic studies is that observations are made in situated contexts—that is, contexts in which technical acts are meaningful, whether from an economic or a cultural point of view. This advantage is evident when one compares results obtained from lab experiments with results obtained from actualistic observations.

Let me give one brief example. With respect to the standardization hypothesis, it is supposed that the rate of ceramic production affects motor habits which, in turn, affect the degree of metric standardization. When measured in terms of coefficient of variation, the latter could then be a proxy for assessing the rate of production, and then the degree of specialization of craftsmen. Research based on the Weber fraction for line-length estimation proposed that a coefficient of variation equal to 1.7 "...represents the highest degree of standardization attainable through manual human production of artifacts. . ." (Eerkens and Bettinger, 2001). However, ethnographic data show that in fact potters (from Spain and India, and not using any ruler) can produce vessels whose coefficient of variation for maximum diameter can be equal to 1.4 (Roux, 2003b). The premise of the theoretical computation raises questions: the skill factor in relationship with the rate of practice has not been taken into account. By comparing technical acts within different extant socio-economic situations, it has been possible to show that the rate of production affects the degree of standardization (that is, the coefficient of variation), given the skills developed by the potters in the course of their practice. In other words, ethnographic enquiry has been necessary to test lab and theoretical data as well as to unravel the mechanism explaining the regularity.

In the domain of technology, complex correlations provide rules of infer-ence with respect to the actualization conditions of technological facts (change or stability) and permit, at a higher level, archaeological interpretations touching upon history of populations. The theory behind their construction is the dynamic system approach, a theory of change found in different disciplines (physics, move-ment sciences, neurosciences, geography, and so on) dealing with complex and changing phenomena. Its major relevance for archaeology is that it distinguishes between historical scenarios and the actualization conditions of these scenarios. Theory in archaeology is mainly concerned with historical scenarios, be it proces-sual, post-processual, behavioural or evolutionary archaeology. The focus is on the forces underlying cultural evolution (e.g. in the case of evolutionary archae-ology, selection and/or decision-making forces [Shennan and Wilkinson, 2001; Spencer, 1997]; in the case of behavioral archaeology, cultural choices [Schiffer and Skibo, 1997]), cultural evolution being understood as the historical scenarios that happened at different times and places. In the dynamic approach, the focus is shifted from the particular, historical forces underlying evolutionary change, to the cross-cultural forces that actualize evolutionary change. With this shift of focus, the key role assigned by evolutionary archaeology to cultural transmission is maintained, but not as an explanatory mechanism of change. Cultural transmission is considered, with the modes of production, as one component of the actualization context of cultural change.

Such a context can be studied in archaeological (Roux, 2003a) and actual-istic (Gelbert, 2003) situations. Actualistic situations provide the short duration necessary for discovering the mechanisms underlying technological changes in different settings. In other words, they give us the opportunity to test contexts of technological change by comparing different ethnographic settings—that is, by changing the parameters, all other things being equal. Such studies will contribute to the large empirical data base very much needed before any general theory on the evolutionary forces behind technological changes or stability can be developed.

The necessity of coupling long term studies with short term studies can be exemplified through Gosselain’s (2000) case study. On the basis of numer-ous ethnographic records, Gosselain has mapped the diffusion of fiber and carved roulettes in sub-Saharan Africa. Different patterns of rouletting have been recorded on archaeological ceramics since 5000 years ago, and are considered as a line of evidence for inferring movements of population. Gosselain examines the distri-bution of fiber and carved roulettes and observes that it is continuous, following the fragmented linguistic belt south of the Sahara, from West to East. He observes that this distribution does not follow social, economic or linguistic boundaries, but rather natural geographical boundaries. Gosselain proposes then that the carved and fiber roulettes spread from West to East through indirect contacts, without major movements of population and that natural boundaries acted as frontiers to its further diffusion.

Two ethnoarchaeological studies, of shorter duration, enable us to discuss and enrich these hypotheses. First, let us consider the results obtained by Livingstone-Smith in Northern Cameroon (2000). Livingstone-Smith examines variability in clay processing. This variability allows him to distinguish between four technical zones. These four technical zones correspond to the pattern of settlement of different ethnic groups, as well as to the density of population. They do not correspond to any techno-functional or geological variability. Livingstone-Smith concludes that the four technical zones are maintained through geographical borders that determine settlement patterns and population densities. These borders act as frontiers and prevent diffusion of technical features, contacts between groups belonging to different technical traditions depending more on geographical proximity than on group affiliation. In dynamic terms, Livingstone-Smith's short-term study sug-gests that such natural boundaries may act as a mechanism for lack of contact and therefore as a condition for preventing the diffusion of technical features (here, features which do not present specific techno-economic advantage). Turning back to Gosselain's case study, Livingstone-Smith's results provide thus relevant refer-ence data for arguing that such natural boundaries may have played a role in the lack of diffusion of carved and fiber roulettes beyond the sub-Saharan belt.

With respect now to the hypothesis of the diffusion of the roulettes through indirect contacts, let us turn to Gelbert's case study (Gelbert, 2003). She reports that, in the Valley of Senegal, among the two ethnolinguistic groups studied (Halpulaar'en and Mande), there are different techniques of decoration. Two of these were originally practiced only by one group (tradition 2, tradition Mande): imprinting by rolling with a corncob, and rocker stamping with a serrated calabash. These techniques have been adopted by Halpulaar'en potters (tradition 1) who have immigrated to the area. Detailed technological analysis shows that borrowing of the rolled corncob technique does not involve any motor, technical or functional constraints. It does not involve acquiring a new tool: they are already used by tradition 1 potters for finishing operations. Also, it does not involve any constraints in raw material acquisition, since tradition 1 potters can adopt corncob decoration while using their habitual clay. Borrowing of the rolled corncob technique arises only from a conscious desire to adapt to the local demand, because the local clientele chooses its pots partly on aesthetic criteria. As a result of the dynamic process involving the different components mentioned above, corncob decoration has been adopted by all the potters belonging to tradition 1. These potters are large-scale producing potters and sell locally; they have permanently immigrated to the upper Senegal Valley. This represents the actualization context of the corncob adoption. The same observations have been made for the rocker stamping with a serrated calabash. Hence, the following rule of inference: if we observe borrowing of any technique of decoration with the same properties as the rolled corncob technique, then we can infer prolonged immersion in the area of the exogenous tradition. Coming back to Gosselain's case study, it appears then that the situation is perhaps more complex than originally thought: a decoration technique can be easy to learn, visible to potters and consumers and still be adopted only after prolonged immersion in the exogenous area.

Short term actualistic studies thus appear to be necessary if we want to understand the mechanisms underlying technological facts, and more precisely how context of production and transmission act as evolutionary forces. As shown by Gelbert's studies, this context may vary depending on the properties of the technological fact: for example, depending on the techno-economic advantage presented by the technique, indirect contact or prolonged immersion may, or may not, cause the borrowing.

CONCLUSION

Building cross-cultural correlates linking material culture with static and dynamic phenomena is an essential task for interpreting the past. Indeed, when they are constructed independently of the historical theories aimed at explaining the archaeological record, the resultant archaeological interpretation may claim objectivity at a first level, which is a major point (Binford, 1978, 1981; Tschauner, 1996). In order to construct such cross-cultural correlates, explanatory mecha-nisms have to be developed according to appropriate methodologies. The latter aims at distinguishing between universals and cultural variation. Explanations of well-founded correlates call upon theoretical frameworks developed within the different domains belonging to the correlates. These explanations can be tested against empirical data. Because cross-cultural correlates relate not only to static phenomena, but also to dynamic phenomena, they participate directly to the study of the evolutionary forces underlying cultural evolution.

Unfortunately, few ethnoarchaeological studies follow methodologies explicitly aimed at constructing cross-cultural correlates. The "library" of rules of inference is not large. Most often, ethnoarchaeological case studies report cultural variation and the particular factors responsible for the variation under study. Only rarely, do they examine constraints derived from the material and anthropological universe. Indeed, even if ethnoarchaeologists appear to agree on the importance of seeking regularities, confusion still exists concerning the appropriate subject of study. As a result, research on regularities founded on universals of properties and process is rare. On the contrary, the mainstream of research focuses on the complexity of the relationships between material culture and the systemic con-text, whereas these very relationships are, by definition, particular and therefore cannot act as reference data. Indeed, a systemic context is the result of a particu-lar scenario, and produces a diversity of variables that express the particularities of the context under study. In order to discover regularities, ethnoarchaeological studies must relate to the universals of properties and process that underlie the diversity of the variables, that is the universals that explain the correlates under study. These regularities will then allow the archaeologist to climb the pyramid of inferences and interpret archaeological facts in terms that are specific to an historical situation for which there is not necessarily any analogue. In this respect, the agenda of ethnoarchaeology is still very stimulating, involving a science of reference necessary for interpreting the past.

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